RAMBOLL ENVIRON

November 19, 2015

TECHNICAL MEMORANDUM

To: File

From: Mark Mejac

Subject: Estimated Groundwater Discharge to Surface Water Dilution Factor
Former Coke Plant, ArcelorMittal, East Chicago, Indiana

This memorandum has been prepared to document an estimated dilution factor associated with groundwater discharge to the Indiana Harbor Ship Canal (IHSC) at the ArcelorMittal Former Coke Plant site in East Chicago, Indiana. The dilution factor is obtained by dividing surface water flow rate within the IHSC by the estimated groundwater discharge rate to the Canal from the former Coke Plant site.

IDEM (pursuant to 327 IAC 5-2-11.4) identifies use of a default dilution factor of up to 25 percent of the design flow, where application of chronic (ecological) mixing zones are used to attain water quality standards in tributaries and connecting channels to the Great Lakes (including the IHSC). IAC regulations also provide for demonstration of alternative dilution capacity to address compliance for both chronic and acute (ecological) criteria. The use of 25 percent of the stream design flow was used as the conservative fraction of total receiving water flow available for dilution of site-related human health-based constituents discharging to flowing surface water. The mean annual discharge for the IHSC at East Chicago (U.S. Geological Survey Station Number 04092750) is 647 cubic feet per second (cfs) (Stewart and others, 2000). Based on use of the 25 percent of the design flow factor identified above, the conservative total receiving surface water flow rate available for dilution is 162 cfs.

The groundwater discharge rate is estimated using Darcy's Law ($Q = KiA$), where:

Q = Discharge rate of groundwater for the area of discharge to the receiving surface water;

K = Representative hydraulic conductivity within the area of discharge to the receiving surface water flow;

i = Representative hydraulic gradient within the area of interest;

A = Cross-sectional area of the interface between the impacted groundwater and surface water.

The following sections provide the basis for the Darcy's Law parameters used as part of this evaluation.

HYDRAULIC CONDUCTIVITY

The estimated hydraulic conductivity of site-specific Calumet aquifer sands is based on the geometric mean of in-situ hydraulic conductivity testing previously conducted on ten shallow monitoring wells at the Former Coke Plant site (STS, 2008). The estimated hydraulic conductivity value, 88 feet per day (ft/d), is equivalent to 3.1×10^{-2} centimeters per second (cm/s). In terms of literature values for horizontal hydraulic conductivities for the Calumet aquifer in Lake County, Indiana, Rosenshein and Hunn (1968) reported estimated hydraulic conductivities from specific-capacity test data to range from 10 to 130 ft/d, with an average value of 60 ft/d. Kay and others (1996) estimated horizontal hydraulic conductivities of the local Calumet aquifer based on slug-test methods, resulting in a range from 4.8 to 30 ft/d, with an

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average value of 17.9 ft/d. Based on the foregoing, the estimated site-specific hydraulic conductivity (88 ft/d) compares favorably with applicable literature values for the local Calumet aquifer sands.

HYDRAULIC GRADIENT

The estimated horizontal hydraulic gradient within the on-site Calumet aquifer sands is based on October 2012 and July 2013 groundwater elevations documented in the September 2015 Ramboll Environ Additional Investigation Report for the Former Coke Plant site. Specifically, the hydraulic gradient is based on the difference between the water table elevation at the furthest upgradient shallow monitoring well at the site (MW-822S), and the reported Lake Michigan surface water elevation for each of those two dates. The October 2012 groundwater elevation at MW-822S was measured to be 584.63 feet relative to mean sea level (MSL), and the July 2013 groundwater elevation at MW-822S was measured to be 585.98 feet MSL. Based on U.S. Army Corps of Engineers data, the October 2012 Lake Michigan water level was 576.57 feet MSL, and the July 2013 Lake Michigan water level was 577.72 feet MSL. The distance between monitoring well MW-822S and the IHSC is approximately 1,810 feet. Therefore, the estimated horizontal hydraulic gradient based on October 2012 data is 0.0045, and the estimated horizontal hydraulic gradient based on July 2013 data is 0.0046. For the purpose of this evaluation, the assumed hydraulic gradient is conservatively assumed (i.e., designed to increase estimated groundwater discharge to the IHSC) to be the larger of the two hydraulic gradients (0.0046).

With respect to literature values for horizontal hydraulic gradients for the Calumet aquifer in Lake County, Indiana, Fenelon and Watson (1993) indicated average horizontal hydraulic gradients of 0.0005 to 0.003, and gradients that approached 0.005 within approximately 500 feet of a groundwater discharge area to surface water. As such, the estimated site-specific hydraulic gradient (0.0046) compares favorably with applicable literature values for the local Calumet aquifer sands in the vicinity of groundwater discharge areas.

GROUNDWATER VELOCITY

Based on a typical effective porosity value for sandy soils of 0.25 (Freeze and Cherry, 1979) and applying the Darcy's Law parameters identified above, the estimated average groundwater flow velocity within the Calumet aquifer sands at the Former Coke Plant site is 1.62 ft/d. Kay and others (1996) calculated horizontal groundwater velocities through the local Calumet aquifer of 0.027 to 0.34 ft/d. Fenelon and Watson (1993) estimated an average horizontal groundwater velocity for the Calumet aquifer of 0.14 ft/d. They further indicated that local, short-term (hours and days) groundwater flow rates could range as high as 0.55 to 0.82 ft/d, especially near discharge areas and particularly when Lake Michigan levels are low. The long-term average (1918 to 2014) Lake Michigan water level is reported by the U.S. Army Corps of Engineers as 578.77 feet MSL. As indicated above, the October 2012 Lake Michigan water level was reported as 576.57 feet MSL, and the July 2013 Lake Michigan water level was reported as 577.72 feet MSL. The October 2012 and July 2013 water levels are substantially lower than the long-term average Lake Michigan water level. As such, the estimated groundwater flow rates used as part of this evaluation are conservatively high, as they are based on unusually low Lake Michigan water levels. Indeed, the estimated average shallow groundwater flow velocity at the Former Coke Plant site (1.62 ft/d) is 2 to 3 times greater than the short-term groundwater flow velocities near discharge areas (0.55 to 0.82 ft/d) estimated by Fenelon and Watson (1993).

CROSS-SECTIONAL AREAS

Breached Sheet Pile Barrier Area

Sheet pile barriers were historically emplaced within the IHSC to define and create the Indiana Harbor Ship Canal. These interlocking walls of sheet steel were driven through the permeable Calumet aquifer and anchored in the underlying low permeability clay confining unit. Figure 2 attached herein shows the

location of a breached area of the existing sheet pile wall. The estimated length of the breached area totals approximately 500 feet. The breach extends to a depth of 25 feet below ground surface, from an elevation of approximately 590 feet MSL (the ground surface) to 565 feet MSL. The estimated saturated aquifer thickness along the breached area is approximately 15 feet. The estimated cross-sectional area of the interface between the groundwater and the IHSC within the breached sheet pile wall is therefore 7,500 square feet.

Non-Breached Sheet Pile Barrier Area

The estimated length of the Former Coke Plant site IHSC shoreline totals approximately 1,300 feet. The saturated aquifer thickness along the sheet pile barrier is approximately 30 feet, from about 580 feet MSL to approximately 550 feet MSL. The estimated cross-sectional area of the interface between the groundwater and the sheet pile barrier is approximately 31,500 square feet (39,000 total square feet less the 7,500 square feet of breached area identified above).

Groundwater elevation data for Coke Plant shallow monitoring wells located in closest proximity to the Indiana Harbor Ship Canal reveal the presence of groundwater mounding that is consistent with the discontinuity in hydraulic conductivity between the Calumet aquifer sands and the sheet pile barrier. Ranges in measured groundwater elevations obtained in October 2012 and July 2013 for the shallow monitoring wells are summarized as follows.

For the October 2012 data, groundwater elevations for those wells near the shoreline where the sheet pile barrier is present (MW-817S and MW-818S) ranged from 581.83 to 582.36 feet, whereas the groundwater elevations for those wells near the shoreline where the sheet pile barrier is absent to a depth of 25 feet (MW-810S, MW-826S and MW-827S) ranged from 577.69 to 580.05 feet. For the July 2013 data, groundwater elevations near the shoreline where the sheet pile barrier is present ranged from 583.70 to 584.92 feet, and the groundwater elevations near the shoreline where the sheet pile barrier is absent ranged from 578.78 to 580.81 feet.

The groundwater elevation data near the sheet pile barrier are approximately 3 to 4 feet greater than in the shoreline area of the sheet pile barrier breach. Based on the available data, the sheet pile barrier is re-directing groundwater flow towards the breached area. In addition, based on information contained in Cohen et al. (2002), hydraulic conductivities in the Calumet aquifer are generally 100 to 10,000 times greater than hydraulic conductivities in the underlying and continuous clay confining unit. Moreover, groundwater flow in the underlying confining unit is mostly vertical with relatively minor amounts of horizontal flow.

The observed groundwater mounding near the sheet pile barrier relative to groundwater levels near the breach, coupled with reported minimal horizontal groundwater flow in the underlying clay confining unit (within which the sheet pile barrier is anchored), lead to the conclusion that groundwater is discharging to the Canal through breaches in the sheet pile wall, rather than to bottom sediments in the Indiana Harbor Ship Canal.

Despite the observed groundwater mounding near the sheet pile barrier and in an effort to identify a conservatively low dilution factor, some leakage through the non-breached sheet pile barrier is assumed. Specifically, groundwater discharge through the non-breached sheet pile barrier is assumed to occur a rate that is 10 percent of the groundwater discharge rate through the breached sheet pile barrier, as further discussed as follows.

Groundwater to surface water discharges along the Indiana Harbor Ship Canal and Lake Michigan shorelines were estimated by AECOM in 2009, based on the results of flow modeling using an analytic

element model known as GFLOW. Based on the results of model calibration and sensitivity analysis, the estimated hydraulic conductivity of the sheet pile revetments is on the order of 5 x 10^{-7} cm/s, which is equivalent to 0.0014 ft/d. For the purpose of estimating a conservatively low dilution factor associated with groundwater discharge to the IHSC at the former Coke Plant, the overall hydraulic conductivity of the non-breached sheet pile barrier is assumed as 10 percent of the estimated hydraulic conductivity of the site-specific Calumet aquifer sands through which groundwater discharges via the breached sheet pile barrier, or 8.8 ft/d (rather than the 0.0014 ft/d value identified above).

GROUNDWATER DISCHARGE TO IHSC SURFACE WATER DILUTION FACTOR

Based on the Darcy's Law parameters identified above, the estimated rate of groundwater discharge through the breached area of the existing sheet pile barrier at the Former Coke Plant site is 15.8 gallons per minute, or 0.0351 cfs. The estimated rate of groundwater discharge through the non-breached area of the existing sheet pile barrier at the Former Coke Plant site is 6.6 gallons per minute, or 0.0148 cfs. The estimated rate of groundwater discharge through the breached and non-breached area of the existing sheet pile barrier at the Former Coke Plant site therefore totals 22.4 gallons per minute, or 0.0499 cfs.

As indicated above, the conservative total receiving surface water flow rate available for dilution is 162 cfs. Based on these values, the estimated dilution factor associated with groundwater discharge to the IHSC at the ArcelorMittal Former Coke Plant site is 3,250.

REFERENCES CITED

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